ABOVE 10TH SCIENCE TEAM MEETING
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WetCH$_4$: A Machine Learning-based Upscaling of Methane Fluxes of Northern Wetlands during 2016-2022

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Introduction

Methane (CH_4) is a potent greenhouse gas that has a global warming potential 28 times greater than CO_2 over a period of 100 years. The major sources of natural CH_4 emissions to the atmosphere are from wetlands. Northern wetlands (>45º N) encompass 4.19±2.22 million km^2 land area, accounting for roughly 40% of global wetland area. Estimates on northern wetland CH_4 emissions are uncertain, ranging 22–49.5 Tg CH_4 yr^{-1}. A detailed understanding of the spatio-temporal variability of CH_4 emission rates remains limited. Data-driven upscaling that uses empirical models, including machine learning (ML) approaches, to simulate CH_4 fluxes provides independent estimates that complement those estimates from process-based models and atmospheric inversions. Here we present a ML upscaling framework (WetCH$_4$) to characterize the spatial and temporal variability of wetland methane fluxes. With WetCH$_4$, we produced daily 10-km methane fluxes across the Arctic and boreal wetlands for 2016-2022.

Site-level observations

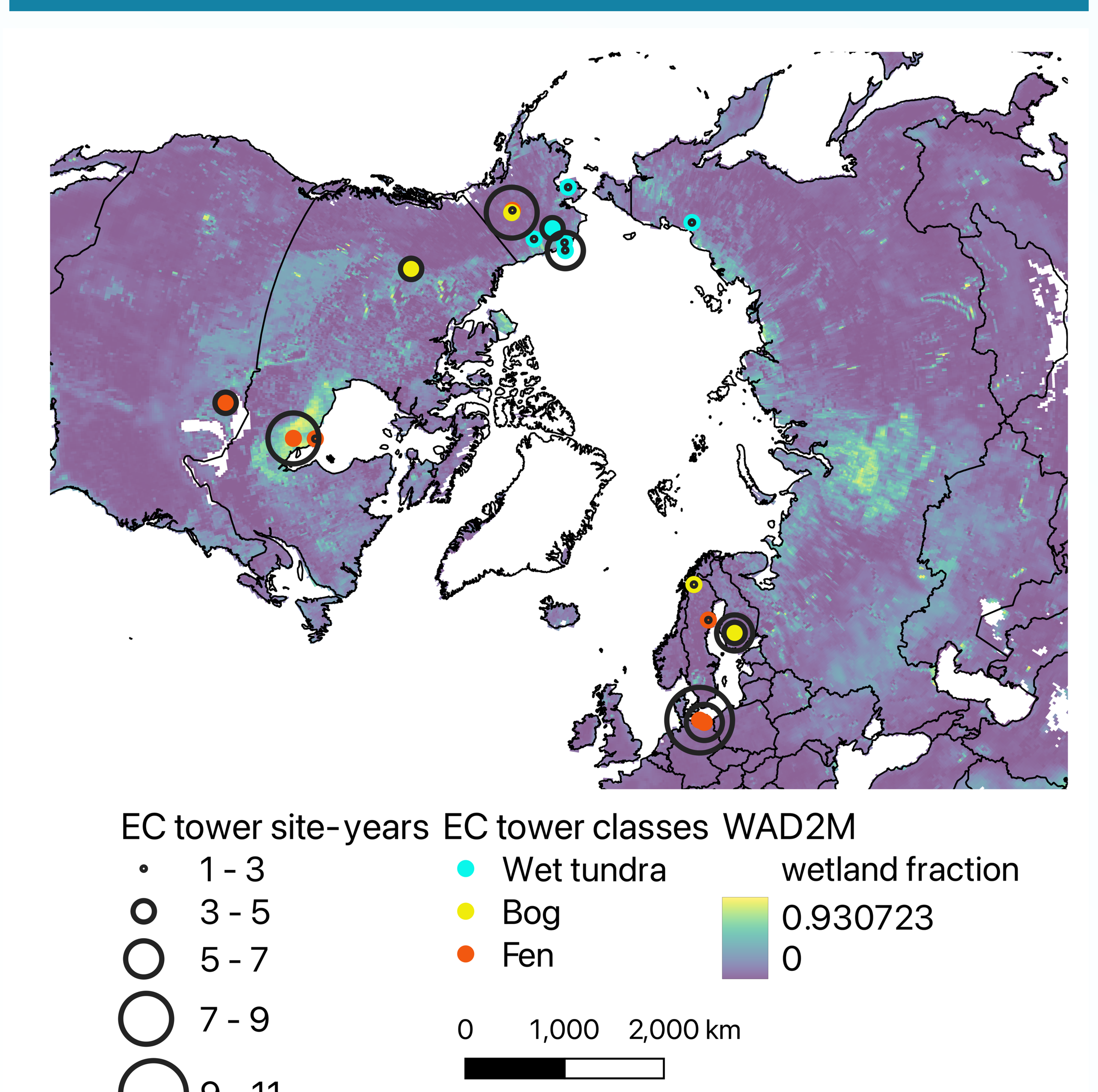

Figure 1. Eddy covariance sites: distribution, class, and data size (site-years) used in WetCH$_4$. The EC data are from the Fluxnet-CH$_4$ database and the contributions of site PIs. The background image shows the maximum annual fractions of wetland cover in 2011-2020 from WAD2M.

Acknowledgments

This research is supported by the TED Audacious Project (Permafrost Pathways). We thank David Olefeldt, Sara Knox, the Fluxnet-CH$_4$ community, and our site PIs, Elyn Humphreys, Michelle Garneau, David Cook, Donatella Zona, Lydia Vaughn, Margaret Torn, Hiroki Iwata.

WetCH$_4$ framework

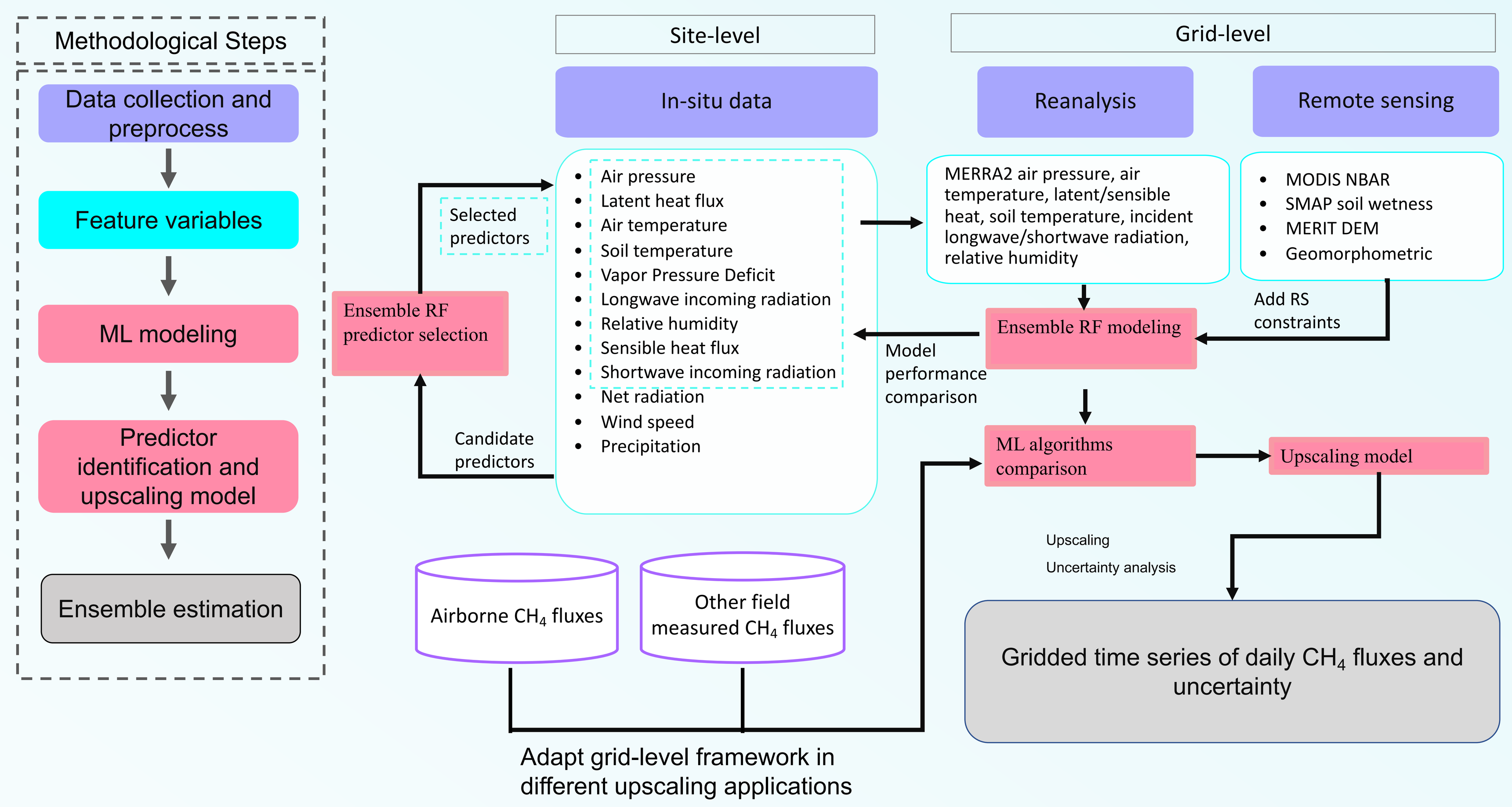

Figure 2. Workflow and experimental design: abstract methodological steps are integrated in the left dash box; detailed framework development is described on the right with colors matching the associated step on the left.

Model validation

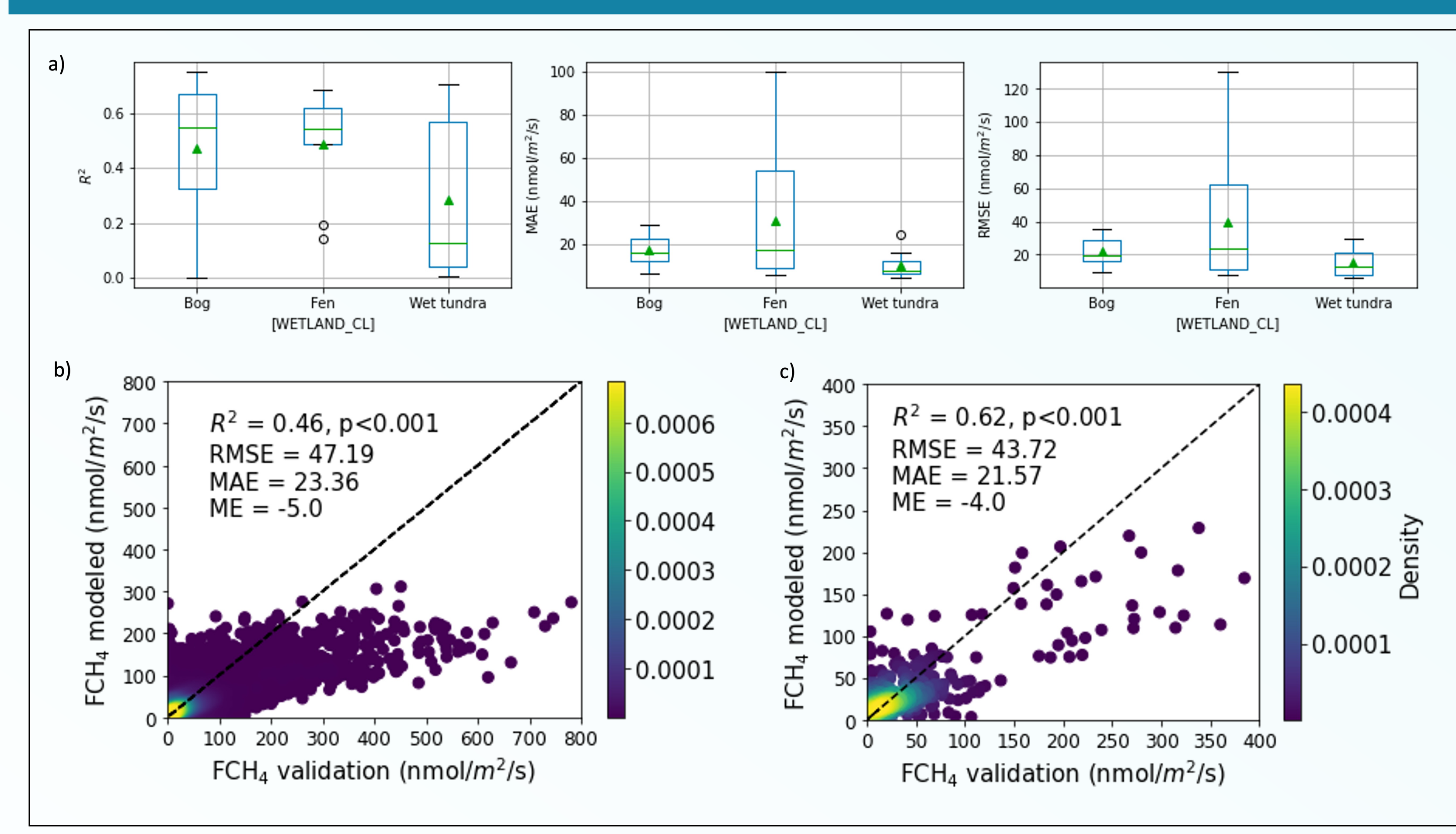

Figure 3. Model predictive performance evaluation on random forests modeled CH_4 fluxes and independent validations: (a) boxplots of R^2, mean absolute error (MAE), and root mean squared error (RMSE) across validation sites by wetland types; (b) pooled daily means density scatter plot; (c) pooled monthly means density scatter plot.

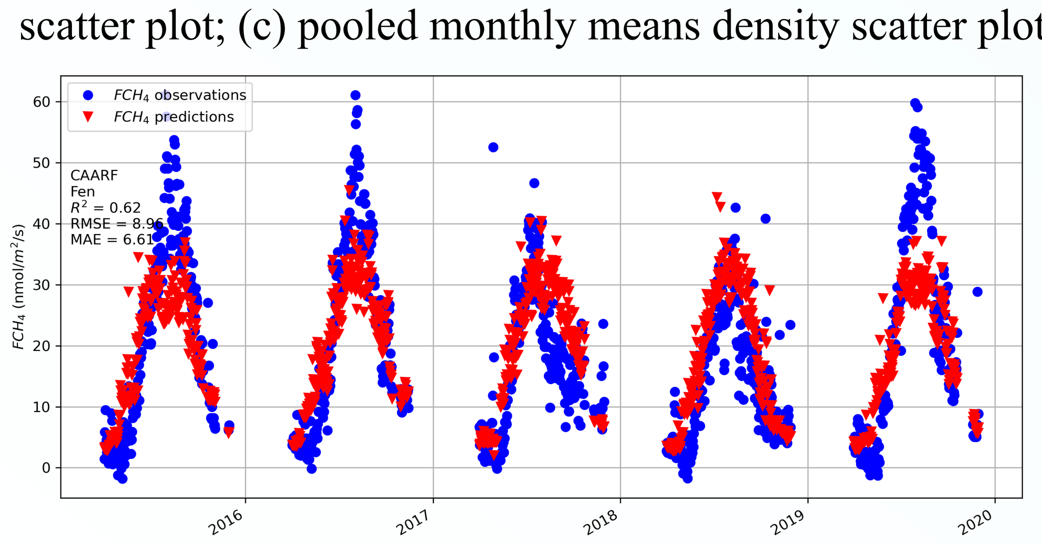

Figure 4. An example of modeled daily CH_4 fluxes versus observations at CA-ARF site.

Scan me!

Reference: Ying, Q., Poulter, B., Watts, J. D., Arndt, K. A., Virkkala, A.-M., Bruhwiler, L., Oh, Y., Rogers, B. M., Natali, S. M., Sullivan, H., Schiferl, L. D., Elder, C., Peltola, O., Bartsch, A., Armstrong, A., Desai, A. R., Euskirchen, E., Göckede, M., Lehner, B., Nilsson, M. B., Peichl, M., Sonnentag, O., Tuittila, E.-S., Sachs, T., Kalhori, A., Ueyama, M., and Zhang, Z.: WetCH4: A Machine Learning-based Upscaling of Methane Fluxes of Northern Wetlands during 2016–2022, Earth Syst. Sci. Data Discuss. [preprint], https://doi.org/10.5194/essd-2024-84, in review, 2024.

Results

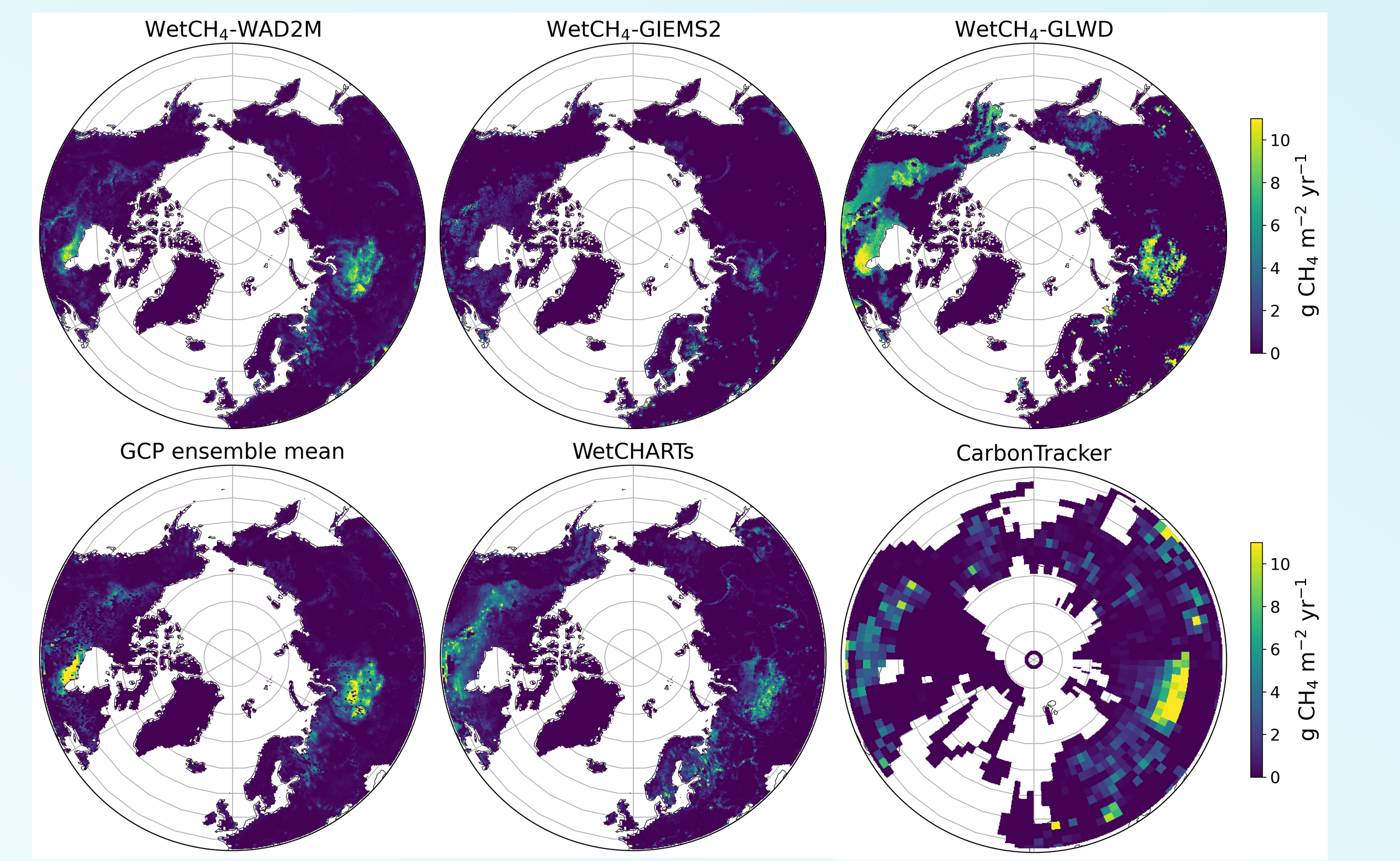

Figure 5. Mean annual wetland CH_4 fluxes: the top row contains WetCH$_4$ upscaled fluxes between 2016 and 2022 and weighted by wetland fractions for three wetland maps including Wetland Area and Dynamics for CH_4 Modeling (WAD2M), Satellite-derived global surface water extent and dynamics (GIEMS2), and the static Global Lakes and Wetlands Database (GLWD); the bottom row contains bottom-up Global Carbon Project (GCP) ensemble mean, the extended ensemble of wetland CH_4 estimates (WetCHARTs), and top-down estimates of CarbonTracker-CH_4 natural microbial emissions.

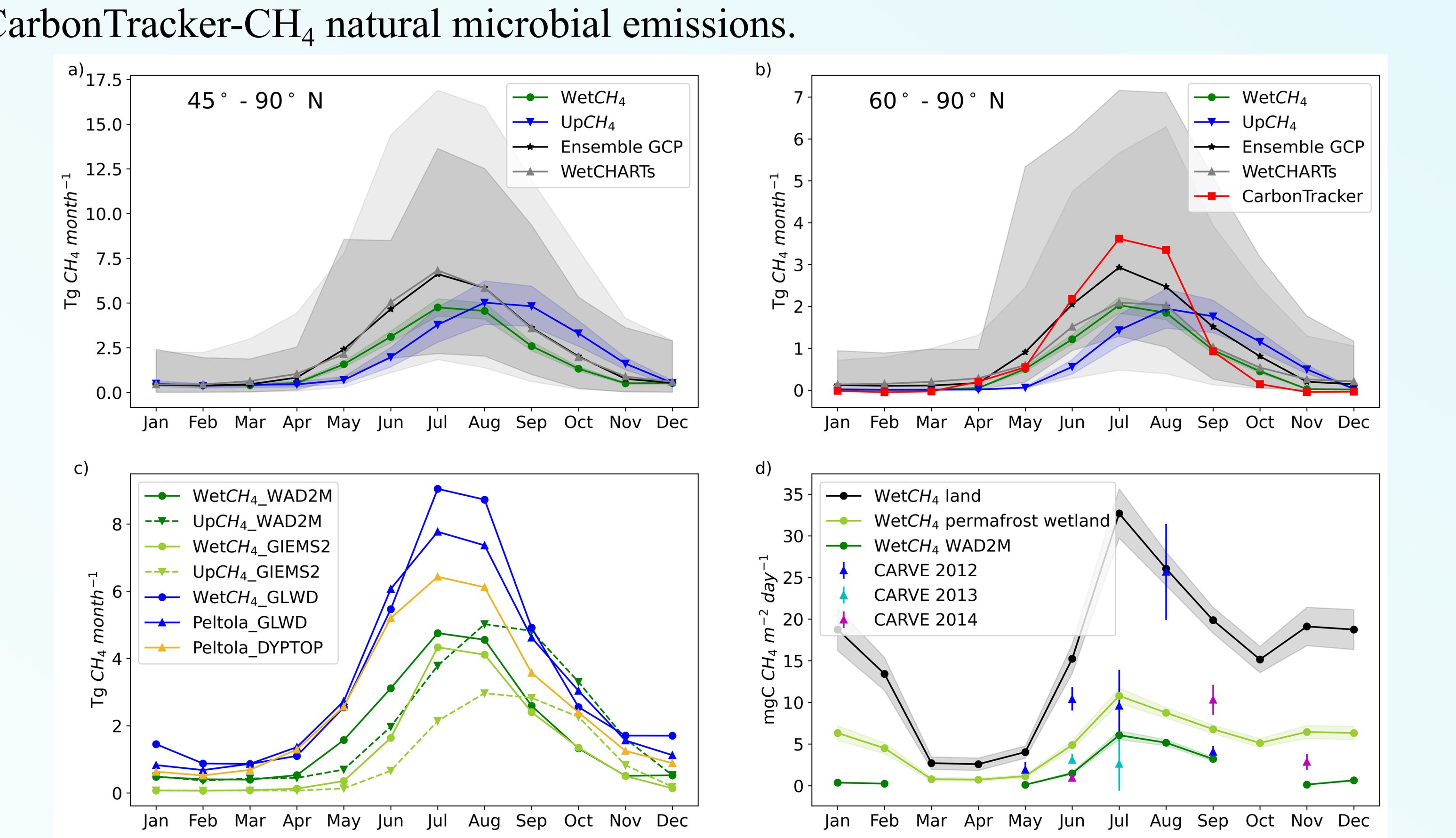

Figure 6. Multi-year average seasonal cycles of wetland CH_4 emissions: (a) ML-upscaled mean seasonal cycles with WAD2M in comparison to process-based models for 45°-90° N; (b) same comparison for 60°-90° N and addition of atmospheric CarbonTracker-CH_4 attributed microbial emissions (2016-2022); (c) compare three ML-upscaled mean seasonal cycles of CH_4 emissions with different wetland area maps; (d) compare WetCH$_4$ mean seasonal cycles over the land (black line), with the permafrost wetland map (olive line), and with WAD2M (green line), to the estimates of CH_4 fluxes in growing seasons from CARVE retrievals in North Slope area of Alaska.

Conclusions and future work

WetCH$_4$ introduced reanalysis soil temperature, satellite soil moisture and surface reflectance in modeling wetland CH_4 fluxes to improve accuracy (R^2 = 0.62). The framework will be applied to model long term wetland CH_4 fluxes with more EC observations compiled and the availability of satellite soil moisture product before 2016 (e.g. ESA Climate Change Initiative soil moisture).